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[REGULAR POSTER TWIN] Tripling the energy coupling efficiency from hohlraum to capsule on NIF

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In the laser-driven indirect drive scheme for inertial confinement fusion (ICF), the capsule diameter is typically limited to ~2 mm in order to attain quasi-round implosions with currently available laser energy in cylindrical hohlraums. This geometrical factor restricts the energy coupling efficiency from the hohlraum to the capsule to be ~10% [Ref.1]. We report the first series of experiments on NIF demonstrating ~ 30% energy coupling to an Al capsule in a rugby-shaped Au hohlraum [Ref.2]. 3.0mm- and 3.4mm-diameter Al capsules are driven in Au rugby hohlraums at 1MJ and 1.5MJ laser energy, respectively. Measurements of in-flight capsule size, mass remaining, velocity, bang time and neutron yield show good agreement with simulations, consistent with ~300kJ coupling at 1MJ drive and ~500 kJ coupling at 1.5MJ drive. It is found that the shell shape during the implosion is sensitive to the rugby dimensions so that the rugby shape is an effective knob for symmetry tuning. A round imploded shell has been achieved near the bang time for the 3.4mm capsule.

In comparison to a conventional cylindrical hohlraum that has a straight wall, the curved wall of a rugby hohlraum [Ref.3,4] affects the laser irradiation mainly in two aspects: enlarging the laser spot size and enhancing the specular reflection of the laser beams. This results in ~1.4-1.8x larger laser spot and lower intensity of the beams, which is helpful to reduce beam blocking due to the wall bubble expansion. The larger incident angle also leads to higher reflection of the beams, which points toward inside of the rugby hohlraum and is helpful to increase the drive at the waist. These beneficial effects and the simulation setup have been discussed in detail in [Ref.5].

The experiments were preformed using a standard 1D and 2D x-ray radiography platform on NIF. The setup is illustrated in Fig. 1 (a). A Zr foil located at 12 mm from the target center was irradiated by 8 NIF beams to generate a 16 keV backlighter. Measurements of the velocity and mass density profile by the streaked radiography provided a shell kinetic energy of 34 kJ with ~1 MJ laser drive, which is 2-4x that which was achieved in the recent high-foot shots with a ~2 MJ laser drive. Given that the typical rocket efficiency for imploding Al ablator is ~ 10%, 34 kJ shell kinetic energy corresponds to > 300 kJ coupled to the capsule. Fig. 1 (b) shows the simulated energy absorption by the capsule at three scales, 0.7x, 0.9x and 1.0x. The energy coupled to the capsule reaches 350, 500, and 650 kJ with 1.0, 1.5 and 2.0 MJ drive, respectively. Good agreement between the simulated and measured quantities including peak radiation temperature, in-flight radius, velocity, shell kinetic energy and shell width supports the high energy coupling at 0.7x scale [Ref.2].

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The sensitivity of the laser energy distribution to the incident angle makes it possible to tune the implosion symmetry by adjusting the rugby wall shape. We have carried 3 NIF shots with different rugby dimensions using a 4-5 ns long reverse-ramp pulse shape with peak power 300-400 TW. The x-ray radiographs are shown in Fig. 2. The wide rugby in Fig. 2 (a) produced a quite prolate shell shape, indicating more drive at the waist than at the laser entrance hole. A narrower rugby with smaller waist diameter in Fig. 2 (b) reduced asphericity. Finally a scale-up of the narrow rugby produced a very round implosion as shown in Fig. 3 (c). This symmetry tunability by rugby wall shape will be very useful for the design of future campaigns.

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Nuclear diagnostics were enabled in another shot at 0.9x scale with 7 mg/cc DT gas fill in the Al capsule, providing additional constraints on the energy coupling to the capsule. The measured nuclear burn history is in good agreement with simulated value as shown in Fig. 2(d). The yield reaches 78% of pre-shot prediction. The good agreement between multiple measurements and simulations indicates a coupling energy of ~ 500 kJ in the 1.5MJ drive experiments [Ref.6].

To summarize, we have performed measurements of symmetry, nuclear bang time, neutron yield, in-flight capsule size, and velocity of Al capsules with diameter 3.0-3.4mm in Au rugby hohlraum. The good agreement between data and simulations indicates 500 kJ coupled to the capsule with 1.5 MJ drive. It is demonstrated that the implosion symmetry can be tuned effectively by adjusting the rugby shape. These results open new opportunities for both the mainline single-shell scheme and the double-shell designs toward ignition in ICF, which is a critical step for the development of IFE.

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